**Average daily gain, blood metabolites, and body composition at first conception in
Hereford, Senepol, and reciprocal crossbred heifers on two levels of winter nutrition
and two summer grazing treatments**

R. B. Simpson, C. C. Chase, Jr, A. C. Hammond, M. J. Williams and T. A. Olson

The online version of this article, along with updated information and services, is located on
the World Wide Web at:
http://jas.fass.org

American Society of Animal Science

www.asas.org

Average Daily Gain, Blood Metabolites, and Body Composition at First Conception in Hereford, Senepol, and Reciprocal Crossbred Heifers on Two Levels of Winter Nutrition and Two Summer Grazing Treatments[1,2,3]

R. B. Simpson[*,4], C. C. Chase, Jr.[*,5], A. C. Hammond[*], M. J. Williams[*], and T. A. Olson[†]

*Agricultural Research Service, USDA, Brooksville, FL 34601-4672
and [†]University of Florida, Gainesville 32611-0910

ABSTRACT: Hereford (n = 48), Senepol (n = 42), and reciprocal crossbred (n = 34) heifers from two consecutive calf crops were stratified by breed, age, and BW to receive bahiagrass (*Paspalum notatum*) hay offered free choice and 150 mg monensin·heifer^{-1}·d^{-1} in addition to either 2.27 kg·heifer^{-1}·d^{-1} of a 75% cracked corn and 25% soybean meal mixture (CS) or .91 kg·heifer^{-1}·d^{-1} of soybean meal (SBM). Heifers in each treatment were divided into two winter pasture replicates and exposed to fertile bulls. In spring of each year, one-half of the heifers from each winter treatment were allotted to either a continuous (CONT) or rotational (ROTA) grazing system on bahiagrass pastures for the summer phase of the study. Heifers supplemented with CS had higher ADG from the beginning of the study to first conception than heifers fed SBM (.39 vs .31 ± .02 kg/d; $P < .01$). Heifers fed CS were younger at first conception than SBM heifers (500 vs 563 ± 32 d of age; $P < .05$) but had similar BW (312 vs 317 ± 7 kg; $P > .10$). During the 2-yr study, a subset of Hereford (n = 12), Senepol (n = 15), and reciprocal crossbred (n = 14) heifers were subjected to urea space measurements to determine body composition at first conception. Change in body composition over time was analyzed by regression and body composition at first conception was predicted from these regressions. At first conception, percentage of empty body fat was not affected by treatment or year; however, percentage of empty body fat tended to be higher in crossbred than in Hereford and Senepol heifers (16.6 vs 14.3 and 14.4 ± .94%; $P < .10$). Stepwise regression of BW, body condition score (BCS), fat thickness (determined by ultrasound), and body composition at first conception on age at first conception revealed that BCS and BW accounted for 55% of the variation in age at first conception ($P < .01$).

Key Words: Heifers, Senepol, Puberty, Body Composition, Body Fat

Introduction

Age at puberty is an important trait of beef replacement heifers. Interest has surrounded mechanisms that trigger the onset of puberty in heifers. One consistent finding in heifers is an increased frequency of LH release as onset of puberty approaches (Day et al., 1984; Jones et al., 1991). Breed, nutrition, and season (photoperiod) are other factors that have been shown to affect age at puberty in heifers. How these factors impinge upon the hypothalamic-pituitary-ovarian axis to initiate estrous cycles has not been fully elucidated.

The suggestion that a critical threshold of body fat is necessary for initiation of menarche in girls (Frisch, 1972; Frisch and McArthur, 1974) has led researchers to investigate this hypothesis in heifers (Hall et al., 1995; Yelich et al., 1995). Hopper et al. (1993)

Table 1. Number of Hereford (H), Senepol (S), and reciprocal crossbred
(CB; H × S and S × H) heifers in the respective winter
and summer treatments and duration of each treatment

| Year and duration | Winter treatment[a] | | | | | |
| | CS | | | SBM | | |
	H	S	CB	H	S	CB
1, 167 d	18	13	8	15	11	10
2, 197 d	8	10	8	7	8	8
Total	26	23	16	22	19	18
	Summer treatment[b]					
	CONT			ROTA		
	H	S	CB	H	S	CB
1, 168 d	13	11	7	16	10	6
2, 161 d	5	8	5	7	8	5
Total	18	19	12	23	18	11

[a]CS = 2.27 kg·heifer^{-1}·d^{-1} of a 75% corn and 25% soybean meal mixture. SBM = .91 kg·heifer^{-1}·d^{-1} of soybean meal. Both supplements contained monensin and bahiagrass hay was offered free-choice.
[b]CONT = continuously grazed 16-ha pasture. ROTA = four rotationally grazed 4-ha pastures. Both treatments were replicated.

suggested that if a critical level of body fat content was necessary for puberty, breed differences in this critical level of fat may exist.

Senepol is a *Bos taurus* breed (Hupp, 1981) that seems to be as tolerant to heat as Brahman (*Bos indicus*; Hammond and Olson, 1994; Hammond et al., 1996). Information is limited regarding the age, weight, and body composition of Senepol heifers at puberty. The objective of this study was to determine the effect of nutrition on various traits at first conception, including body composition, in Hereford, Senepol, and reciprocal crossbred heifers.

Procedures

Spring-born Hereford, Senepol, and reciprocal crossbred heifers (n = 124; 278 ± 2 d of age and 226 ± 3 kg, initially; Table 1) from two consecutive years were used to study the effect of winter nutrition level and summer grazing management on ADG, BW and body condition score (BCS) at initial conception, and blood metabolites.

Following a 2-wk adjustment period after weaning in late fall, heifers were stratified by breed, age, and BW to receive bahiagrass (*Paspalum notatum*) hay offered free-choice and 150 mg of monensin·heifer^{-1}·d^{-1} in either 2.27 kg·heifer^{-1}·d^{-1} of a 75% cracked corn and 25% soybean meal mixture (**CS**; n = 65) or .91 kg·heifer^{-1}·d^{-1} of soybean meal (**SBM**; n = 59). Heifers in each treatment were divided into two winter pasture replicates and supplements were fed on Monday, Wednesday, and Friday of each week. Experiment d 0 for the winter treatment phase was November 1, 1990, for yr 1 and October 22, 1991, for yr 2.

When forage availability was adequate in the spring of each year, half of the heifers from each winter treatment were allotted to either a continuous (**CONT**) or rotational (**ROTA**) grazing system on bahiagrass pastures. The CONT system used a 16-ha pasture, and the ROTA system used an equivalent 16 ha that was divided into four 4-ha pastures that were rotationally grazed at weekly intervals. Each grazing system was replicated. Experiment d 0 for the summer treatment phase was April 17, 1991, for yr 1 and May 6, 1992, for yr 2.

Throughout the study, heifers were exposed to fertile Angus bulls equipped with chin-ball markers. Age at first conception was determined based on calving date (minus 284 d for gestation). Chin ball marks on heifers were used to confirm estrus activity at the calculated time of first conception.

Heifer BW and BCS were recorded at 28-d intervals. The BCS system that was used included three relative degrees of emaciation (BCS = 4, 5, and 6), 2.5 mm of estimated fat over the longissimus muscle (BCS = 7), and one unit increase for each 1.3-mm increase of estimated fat over the longissimus muscle (BCS = 8, 9, and 10; Hammond et al., 1992). Average daily gains were calculated within each respective winter and summer treatment period and from the initiation of the winter treatment period to the date of conception. Plasma concentrations of urea nitrogen (**PUN**) and glucose (**GLU**) were determined from blood samples collected on d 0, 56, 112, and 167 of the winter period and on d 0, 84, and 140 of the summer period. Concentration of PUN was determined by a modification of the automated diacetylmonoxime method of Marsh et al. (1965; Industrial Method 339-01, Technicon Industrial Systems, Tarrytown, NY). Concentration of GLU was determined

by an automated method (Industrial Method 339-19; Technicon Industrial Systems, Tarrytown, NY) based on the glucose oxidase procedure described by Gochman and Schmitz (1972).

Body Composition Measurements in Subset of Heifers

Body composition at the time of first conception was determined in a subset of representative Hereford (n = 12), Senepol (n = 15), and reciprocal-crossbred (n = 14) heifers (277 ± 3 d of age and 240 ± 5 kg, initially). Beginning 60 d after initiation of the study and at 56-d intervals throughout the study, heifers were subjected to urea space (**US**) measurements and fat thickness over the longissimus muscle (**FT**) was determined by ultrasound.

Urea space was determined by methods similar to those reported by Hammond et al. (1984). Briefly, a peristaltic pump was used to infuse urea into each heifer via an indwelling jugular catheter (approximately 130 mg urea/kg BW of a 20% solution, wt/vol, in .9% saline infused over 2 min). The precise urea dose was determined gravimetrically. Duplicate blood samples were collected immediately before infusion and 12 min after the midpoint of infusion and analyzed for PUN. Urea space was calculated by dividing the precise quantity of urea N infused by the difference in PUN concentration before and after infusion.

Within 2 wk of each US measurement, four contemporary heifers representing each treatment and breed were humanely slaughtered to determine gut fill and facilitate empty BW estimation of all heifers. Empty BW was determined by the sum of total hot carcass and noncarcass fractions following removal of contents of the gastrointestinal tract and bladders. Empty body water, protein, and fat values were derived through prediction equations using urea space and empty BW (Hammond et al., 1984, 1988). Values (%) for empty body water, protein, and fat were calculated by dividing each component by the estimated empty BW of each heifer. Body composition over time was estimated for each heifer using linear regression, and body composition at first conception was calculated using these regressions.

Statistical Analyses

Winter and Summer Phases. Average daily gain, PUN, and GLU during the winter and summer phases of the study were analyzed by ANOVA for the effect of breed, treatment, breed × treatment, and year using the GLM procedure of SAS (1985). The mean square for pasture replicate within breed × treatment × year was used as the error term to test the above variables. Likewise, the mean square for pasture replicate × day within breed × treatment × year was used as the error term for day, breed × day, treatment × day, and breed × treatment × day. Orthogonal contrasts were used to compare differences in means among treatments and breeds.

Body Composition Data. Body composition variables (empty BW, empty body protein, empty body water, empty body fat, FT, and live BW) were independently regressed over time to allow prediction of body composition at first conception for each heifer. Each variable for individual heifers was tested for linear and quadratic effects, and the regression equation of the highest order was used when significant (*P* < .05). All body composition observations were within ± 250 d of conception.

Heifer BW, age, and body composition variables at first conception were analyzed with ANOVA for effect of year, treatment (winter and summer treatment combinations), breed, and appropriate interactions using the GLM procedure of SAS (1985). The mean square for year × treatment × breed was used as the error term to test the effect of winter and summer treatments. Orthogonal contrasts were used to compare the effects of breed (Hereford vs Senepol and purebred vs crossbred), winter treatment (CS vs SBM), summer treatment (CONT vs ROTA), and the winter treatment × summer treatment interaction. Stepwise regression procedures (SAS, 1985) were used to determine the relative importance of BW, BCS, and body composition variables on age at first conception.

Results

Winter and Summer Phases

During the winter phase of the study, ADG was higher in CS than in SBM heifers (.38 vs .25 ± .02 kg/d, respectively; *P* < .01). Winter ADG was also higher in Hereford than in crossbred heifers and higher in crossbred than in Senepol heifers (.40, .33, and .23 ± .02 kg/d, respectively; *P* < .01). Year of study tended to affect winter heifer gain; ADG (kg/d) was lower in yr 1 than in yr 2 (.30 vs .34 ± .02; *P* < .08). Summer treatment did not affect summer ADG; however, summer ADG (kg/d) was higher in crossbred (.40) than in Hereford (.32) heifers and was intermediate in Senepol heifers (.37; SE = .02; *P* < .10). Summer ADG was lower in yr 1 than in yr 2 (.31 vs .42 ± .02 kg/d; *P* < .01). There was no treatment × breed interaction for ADG in either the winter or summer phase of the study.

Body condition score during the winter was higher in CS than in SBM heifers (8.1 vs 7.4 ± .1; *P* < .01). Also, BCS was higher on d 0 and 56 than on d 112 and 167 of the winter phase (8.1 and 8.1 vs 7.4 and 7.4 ± .1, respectively; *P* < .01). Neither grazing management (CONT vs ROTA) nor day of experiment (0, 84, and 140) affected BCS during the summer. However, summer phase BCS was higher in crossbred (7.8)

Table 2. Effect of winter treatment and day on plasma concentration of urea nitrogen[a]

| Day | Winter treatment[b] | | SE | Probability[c] |
	CS	SBM		
	mg/dL			
0	11.6	12.7	.63	> .10
56	16.0	32.5	.60	< .01
112	11.7	18.1	.61	< .01
167	14.2	20.7	.64	< .01

[a]Treatment × day ($P < .01$).
[b]CS = 2.27 kg·heifer^{-1}·d^{-1} of a 75% corn and 25% soybean meal mixture. SBM = .91 kg·heifer^{-1}·d^{-1} of soybean meal. Both supplements contained monensin and bahiagrass hay was offered free-choice.
[c]Probability of effect due to winter treatment.

Table 4. Effect of winter treatment on age and BW at puberty in beef heifers

| Variable | Winter treatment[a] | | SE | Probability[b] |
	CS	SBM		
No. of heifers	49	38	—	—
Age, d	500	563	31.9	< .10
BW, kg	312	317	6.9	> .10

[a]CS = 2.27 kg·heifer^{-1}·d^{-1} of a 75% corn and 25% soybean meal mixture. SBM = .91 kg·heifer^{-1}·d^{-1} of soybean meal. Both supplements contained monensin and bahiagrass hay was offered free-choice.
[b]Probability of effect due to winter treatment.

than in Senepol (7.3) heifers, with Hereford (7.5) being intermediate (SE = .1; $P < .05$). Body condition score was lower in yr 1 than in yr 2 (7.1 vs 8.0 ± .1; $P < .01$).

There was a treatment × day interaction ($P < .05$) for winter phase and summer phase PUN concentrations. Although similar on d 0, PUN was higher in SBM than in CS heifers on d 56, 112, and 167 of the winter phase (Table 2) and higher in CONT than in ROTA heifers on d 84 and 140 of the summer phase (Table 3). Plasma urea nitrogen during winter was higher in yr 1 (18.1 mg/dL) than in yr 2 (16.2 mg/dL; SE = .7 mg/dL, $P < .05$), but year of study did not affect summer concentrations of PUN.

Winter phase plasma GLU was higher in CS than in SBM heifers (84 vs 81 ± 1 mg/dL; $P < .01$). In contrast to winter PUN concentrations, there was no treatment × day interaction for plasma GLU in winter, but there was a breed effect on GLU; Senepol and crossbred had higher GLU than Hereford heifers (85, 83, and 79 ± 1.0 mg/dL, respectively; $P < .01$). Summer concentrations of plasma GLU were also higher in crossbred and Senepol than in Hereford heifers (77 and 78 vs 72 ± 1 mg/dL; $P < .01$). Plasma GLU followed the same pattern as summer concentra-

tions of PUN, declining with each sampling day (82, 74, and 71 ± 1 mg/dL on d 0, 84, and 140, respectively; $P < .01$). No treatment effect or treatment × day interaction was detected for summer concentrations of GLU.

Performance Preceding First Conception

Heifers fed CS had higher ADG from the beginning of the study to first conception than heifers fed SBM (.39 vs .31 ± .02 kg/d; $P < .01$). Although ADG was higher in heifers fed CS, heifer BW at first conception did not differ between CS and SBM heifers because heifers supplemented with CS tended ($P < .10$) to be younger at first conception than SBM heifers (Table 4). No other independent variable affected age at first conception.

In yr 1, ADG to first conception was higher in Hereford and crossbred than in Senepol heifers (.39 and .38 vs .22 ± .02 kg/d); however, no difference in ADG to first conception was observed among breeds in yr 2 (.39, .38, and .35 kg/d for Hereford, crossbred, and Senepol heifers, respectively; year × breed interaction, $P < .05$). No difference in BW at first conception was detected among Hereford (307 kg), Senepol (318 kg), or crossbred heifers (319 kg; $P > .10$; Table 5). Crossbred heifers tended to reach first conception at an earlier age than Senepol heifers, and Hereford heifers were intermediate (478, 568, and 550 d of age, respectively, $P < .10$).

*Traits and Body Composition
at First Conception
in a Subset of Heifers*

In the subset of representative heifers in which urea space measurements were taken, heifers receiving CS were younger ($P < .05$) at first conception but had BW similar ($P > .10$) to those of SBM heifers (459 vs 548 ± 39.7 d and 307 vs 315 ± 5.6 kg, respectively). Breed did not affect age or BW at first conception in the subset of heifers (508, 542, and 461 ± 34.4 d and 299, 294, and 324 ± 14.4 kg for Hereford, Senepol, and crossbred, respectively; $P > .10$).

Table 3. Effect of summer grazing treatment and day on plasma concentration of urea nitrogen[a]

| Day | Summer treatment[b] | | SE | Probability[c] |
	CONT	ROTA		
	mg/dL			
0	17.7	17.4	.56	> .10
84	7.8	4.6	.57	< .01
140	7.4	4.9	.58	< .01

[a]Treatment × day ($P < .05$).
[b]CONT = continuously grazed 16-ha pasture. ROTA = four rotationally grazed 4-ha pastures. Both treatments were replicated.
[c]Probability of effect due to summer treatment.

SIMPSON ET AL.

Table 5. Effect of breed on age and BW at puberty in beef heifers

| | Breed | | | | |
Variable	Hereford	Senepol	Crossbred[a]	SE	Probability[b]
No. of heifers	34	32	21	—	—
Age, d	550	568	478	29.4	< .10
BW, kg	307	318	319	6.4	> .10

[a]Reciprocal crosses, Hereford × Senepol and Senepol × Hereford.
[b]Probability of effect due to breed.

However, ADG (kg/d) from the start of the study to first conception was higher (SE = .03; $P < .05$) in Hereford (.40) and crossbred (.39) than in Senepol (.27) heifers.

The percentage of empty body water and protein were higher in SBM than in CS heifers in yr 1 but were similar in yr 2 (Table 6; treatment × year interaction, $P < .05$). Percentage of empty body fat was not affected by treatment or year.

Crossbred heifers tended ($P < .10$) to have a higher percentage of empty body fat, and a lower percentage of empty body protein at first conception, than purebred heifers (Table 7). Percentage of empty body water was also lower ($P < .05$) in crossbred than in Hereford and Senepol heifers.

At first conception, FT was greater in CS than in SBM heifers (4.5 vs 3.7 ± .22 mm; $P < .01$; Table 6). A treatment × breed interaction was not detected for FT. Heifer BCS at first conception did not differ between winter treatments (8.0 and 7.5 ± .37 for CS and SBM heifers, respectively; $P > .10$).

Crossbred heifers had greater FT at first conception than Hereford or Senepol heifers (4.5 vs 3.8 and 3.9 ± .2 mm, respectively; $P < .05$; Table 7). Heifer BCS followed a trend similar to FT, but the differences due to breed for BCS at first conception were not significant (8.1 vs 7.6 and 7.4 ± .32 for crossbred, Hereford, and Senepol, respectively; $P > .10$).

Stepwise regression revealed that heifer BCS accounted for 36% of the variation in age at first conception ($P < .01$), and BW and BCS together accounted for 55% of the variation. Adding FT and the percentage of body fat and protein to the model only increased the r^2 to 57%.

Discussion

The results reported here indicate that 1) heifers supplemented with CS during the winter phase of this study had higher ADG, higher plasma GLU, and lower PUN, and reached conception at a younger age with greater FT than heifers supplemented with SBM; 2) grazing management (CONT vs ROTA) during the summer phase of the study did not influence any variable measured, with the exception of PUN, which was higher in CONT heifers than in ROTA heifers; 3) concentrations of plasma GLU were lower in Hereford than in Senepol and crossbred heifers during the winter and summer phases; 4) the percentage of empty body fat was not affected by winter or summer treatment, but crossbred heifers tended to have a higher percentage of empty body fat and had greater FT at first conception than purebred heifers; and 5) heifer BW and BCS were important indicators of age at first conception.

Frisch (1976) hypothesized that a critical body composition, specifically a critical level of body fat, initiates estrous cyclicity (puberty). If true, the application of this hypothesis to heifers could possibly

Table 6. Effect of year and winter treatment on percentages of empty body components and fat thickness over the longissimus muscle (FT) at puberty in a subset of beef heifers

| | Year 1 | | Year 2 | | | Probability | |
Variable	CS[a]	SBM[b]	CS	SBM	SE	Year	Treatment
No. of heifers	11	9	11	10	—	—	—
Empty body protein, %[c]	17.8	18.3	18.3	18.2	.23	> .10	> .10
Empty body water, %[c]	60.0	62.1	62.5	62.1	.86	< .10	> .10
Empty body fat, %	16.9	14.4	14.3	14.7	1.46	> .10	> .10
FT, mm	4.3	3.4	4.6	4.0	.25	< .05	< .05

[a]CS = 2.27 kg·heifer^{-1}·d^{-1} of a 75% corn and 25% soybean meal mixture.
[b]SBM = .91 kg·heifer^{-1}·d^{-1} of soybean meal. Both supplements contained monensin and bahiagrass hay was offered free-choice.
[c]Year × winter treatment ($P < .05$).

Table 7. Effect of breed on percentages of empty body components and fat thickness over the longissimus muscle (FT) at puberty in a subset of beef heifers

Variable	Breed			SE	Probability[b]
	Hereford	Senepol	Crossbred[a]		
No. of heifers	12	15	14	—	—
Empty body protein, %	18.3	18.3	17.9	.13	< .10
Empty body water, %	62.2	62.2	60.5	.50	< .05
Empty body fat, %	14.3	14.4	16.6	.94	< .10
FT, mm	3.8	3.9	4.5	.19	< .05

[a]Reciprocal crosses, Hereford × Senepol and Senepol × Hereford.
[b]Probability of effect due to breed.

lead to designation of "target fat levels" for replacement heifers before first breeding, instead of the target breeding BW approach that is currently recommended. However, Bronson and Manning (1991) reviewed evidence that supported the critical body fat hypothesis for the initiation of puberty in females, as well as evidence against this hypothesis, and they suggested that body fat does not play the central role in the energetic regulation of ovulation.

When the relative importance of BW, BCS, FT, and body composition at first conception on age at first conception was tested in the present study, BCS and BW accounted for 55% of the variation in age at first conception ($P < .001$). Fat thickness over the ribeye and the percentages of empty body fat, protein, and water did not contribute significantly to the variation in age at first conception. This suggests that at the relatively low rates of gain that were observed in this study, BCS and BW at first conception were the most informative factors for predicting age at first conception in heifers. If this relationship exists over a wide variety of conditions and breeds, its usefulness in production settings would be high, given the relative ease of obtaining BW and BCS data.

Collectively, a number of studies provide evidence that body fat, per se, is not the sole factor that triggers the onset of puberty in heifers. McShane et al. (1989) decreased fat thickness in heifers by administering bovine somatotropin but did not affect onset of puberty. Simpson et al. (1991) observed increased fat thickness, but delayed onset of puberty, in heifers that were immunized against growth hormone-releasing factor. Hall et al. (1994) administered somatotropin to heifers and altered metabolism in a manner consistent with reduced body fat but did not affect the prepubertal increase in LH secretion or the onset of puberty.

Additional research has focused on more direct measurements of carcass components to determine body composition in beef heifers. Hopper et al. (1993) reported that heifers gaining 1.0 kg/d from weaning to puberty tended to be younger at puberty, with more subcutaneous fat, than heifers gaining .5 kg/d. Hall et al. (1995) reported that the percentage of fat at

puberty was greater in heifers fed to gain 1.0 kg/d than in heifers fed to gain .6 kg/d. Yelich et al. (1995) found that heifers fed to gain 1.4 kg/d reached puberty earlier and at a heavier BW, had a higher BCS, subcutaneous fat thickness, and higher proportion of carcass lipid at puberty than heifers fed to gain .7 kg/d, or .2 kg/d for 16 wk and then 1.4 kg/d until puberty. Consistent with other investigators, these authors concluded that puberty did not occur at a constant body composition or metabolic status in all beef heifers and that other factors in addition to the percentage of body fat apparently regulate puberty in beef heifers.

These studies (Hopper et al., 1993; Hall et al., 1995; Yelich et al., 1995) showing nutritional (or weight gain) effects on body composition at puberty in beef heifers were conducted at much higher nutritional inputs and daily gains than the present study and were conducted at locations that typically develop heifers to calve first at 2 yr of age. In the present study, we examined planes of nutrition that were more typical of Florida conditions under which heifers would calve first at 3 yr of age. Consequently, the difference in daily gain between treatments in the present study was smaller than the differences reported in previous studies. Thus, the difference in body composition of heifers gaining .3 vs .4 kg/d in this study might be expected to be smaller than in heifers gaining .5 vs 1.0 kg/d (Hopper et al., 1993), .6 vs .9 kg/day (Hall et al., 1995), or .7 vs 1.4 kg/d (Yelich et al., 1995).

Hopper et al. (1993) found that Angus had a greater percentage of fat in the carcass at puberty than Santa Gertrudis heifers and suggested that if a critical level of body fat content was necessary for puberty, breed differences in the critical level of fat may exist. In the present study, the percentage of empty body fat at first conception tended to be higher in crossbred than in purebred heifers. This observation, coupled with the finding that crossbred heifers were younger at first conception, lends some credence to the possibility that body fat (but not a critical level of body fat) may be a factor in the onset of puberty in heifers. However, we cannot verify that any effect of body fat in this study was exerted independently of ADG.

The ADG observed in the present study closely match those reported by Wiltbank et al. (1969) for heifers on a low level of feed. In that study, crossbred heifers on the low level of feed reached puberty earlier than straightbred heifers. Other work has also shown a heterotic effect on age at puberty in heifers (Laster et al., 1972), an effect that is seemingly imparted in addition to that exerted through higher ADG alone (Wiltbank et al., 1966). Our findings substantiate this, because, in total, crossbred heifers reached first conception at a younger age, even though their ADG to first conception was not consistently higher than that of purebred heifers.

The higher ADG in CS heifers during the winter phase indicates a beneficial response to energy supplementation under the conditions of this study. As expected, BCS mirrored ADG, with BCS also being higher in CS than in SBM heifers during the winter. The higher FT at first conception in CS than in SBM heifers is also consistent with their higher ADG to first conception. Heifer BCS during the summer was lower in yr 1 than in yr 2, as was summer ADG.

Although Senepol cattle are tropically adapted, Senepol are a *Bos taurus* breed without *Bos indicus* influence (Hupp, 1981). Senepol heifers gained the slowest of all breeds during the winter phase, but during the summer phase, ADG for Senepol heifers was intermediate and ADG of crossbred heifers was the highest. The change in rank for Senepol heifers between winter and summer was likely due to their superior ability to tolerate heat in the summer. The advantage for crossbred heifers in summer ADG was likely a result of heterosis, in addition to the probability that 50% Senepol composition was sufficient to provide considerable heat tolerance in the crossbred heifers (Hammond et al., 1996).

Given their docile temperament and adaptation to a subtropical environment (Hammond et al., 1996), Senepol and Senepol-cross cattle could prove to be a feasible alternative to *Bos indicus* cattle in the hot, humid environment of Florida and the U.S. Gulf Coast. The extent of their use will be largely dependent on several factors, including their durability, carcass characteristics, and reproductive function. Concrete conclusions regarding the overall reproductive performance of Senepol females cannot be drawn from this study; however, the mean age at first conception of purebred Senepol heifers over a 3-yr experiment, of which the heifers in the present study were a part, was 20.0 mo and was younger than the age at first conception of contemporary Brahman heifers (23.0 mo; Chase et al., 1997). It remains to be determined whether purebred Senepol heifers will consistently reach puberty by 400 to 450 d of age when fed and managed to gain at higher rates than those achieved in the present study. It does seem that crossbred Senepol heifers have the ability to reach puberty and first conception at an acceptable age.

Concentrations of PUN were measured in the present study to provide an indication of the relative protein and energy intakes of the heifers. Hammond et al. (1993) found that response to protein supplementation in growing cattle on tropical grass pasture was greater when PUN was below 9.0 mg/dL than when PUN was above 12.0 mg/dL. Concentrations of PUN remained relatively high during the winter but fell below 9.0 mg/dL in CONT and ROTA heifers during the late summer, suggesting that the heifers may have responded to protein supplementation at that time. Low crude protein and low digestibility are typical of tropical grasses, such as bahiagrass, during late summer (Williams et al., 1991). The higher PUN in CONT than in ROTA may be attributable to selective grazing of higher-quality forage by heifers in the CONT grazing system as previously reported (Williams and Hammond, 1996).

The finding that CS heifers in the present study possessed higher concentrations of plasma GLU and were younger at first conception than SBM heifers could indicate a role for GLU in the onset of puberty. However, this pattern (higher GLU and earlier age at first conception) did not hold true when assessing a possible similar relationship among the different breeds used in the present study. Even though the availability of a metabolic fuel such as GLU is assumed to be important, the exact role of GLU in the reproductive function of ruminant females has not been fully elucidated. Phlorizin-induced hypoglycemic beef cows exhibited a suppressed pulse amplitude of LH (Rutter and Manns, 1987; Rutter and Manns, 1988). However, administration of GLU did not enhance secretion of gonadotropins or ovarian activity in postpartum cows (McCaughey et al., 1985) or ewes (Rutter and Manns, 1986).

In summary, the levels of empty body fat reported in the present study closely matched the range of fat or lipid levels reported previously in heifers of a variety of breeds (Brooks et al., 1985; Meinert et al., 1992; Hopper et al., 1993; Hall et al., 1995; Yelich et al., 1995). If a critical threshold of body fat is required to initiate puberty in heifers, then a similar body fat content should consistently be found at puberty or at first conception within a given study, which was not the case in previous investigations. In our study, empty body fat at first conception tended to differ among breeds but did not differ among treatments (although it tended to be higher in CS than in SBM heifers in yr 1; Table 6).

Implications

The observation that heifer body weight and body condition score were the main contributors to variation in age at first conception suggest that these easily obtained measurements can be used to help predict

early heifer reproductive performance; however, these measurements at first conception were shown to be influenced by nutrition. It is likely that other factors in addition to body weight, body condition score, and body composition initiate the onset of puberty and first conception in beef heifers, or a multiple trigger involving body weight, body weight gain, body composition, and(or) age variation may be involved.

Literature Cited

Bronson, F. H., and J. M. Manning. 1991. The energetic regulation of ovulation: A realistic role for body fat. Biol. Reprod. 44: 945–950.

Brooks, A. L., R. E. Morrow, and R. S. Youngquist. 1985. Body composition of beef heifers at puberty. Theriogenology 24: 235–250.

Chase, C. C., Jr., M. J. Williams, A. C. Hammond, and T. A. Olson. 1997. Effect of winter nutrition and summer bahiagrass grazing system on growth and puberty among breeds of heifers. J. Anim. Sci. 75(Suppl. 1):19 (Abstr.).

Day, M. L., K. Imakawa, M. Garcia-Winder, D. D. Zalesky, B. D. Schanbacher, R. J. Kittok, and J. E. Kinder. 1984. Endocrine mechanisms of puberty in heifers: Estradiol negative feedback regulation of luteinizing hormone secretion. Biol. Reprod. 31: 332–341.

Frisch, R. E. 1972. Weight at menarche: Similarity for well nourished and undernourished girls at differing ages, and evidence for historical constancy. J. Pediatr. 50:445–450.

Frisch, R. E. 1976. The physiological basis of reproductive efficiency. In: D. Lister, D. N. Rhodes, V. R. Fowler, and M. F. Fuller (Ed.) Meat Animals, Growth and Productivity. p 327. Plenum Press, New York.

Frisch, R. E., and J. McArthur. 1974. Menstrual cycles: Fatness as a determinant of minimum weight for height necessary for their maintenance or onset. Science (Wash., DC) 185:949–951.

Gochman, N., and J. M. Schmitz. 1972. Application of a new peroxide indicator reaction to the specific, automated determination of glucose oxidase. Clin. Chem. 18:943–950.

Hall, J. B., K. K. Schillo, B. P. Fitzgerald, and N. W. Bradley. 1994. Effects of recombinant bovine somatotropin and dietary energy intake on growth, secretion of luteinizing hormone, follicular development, and onset of puberty in beef heifers. J. Anim. Sci. 72:709–718.

Hall, J. B., R. B. Staigmiller, R. A. Bellows, R. E. Short, W. M. Moseley, and S. E. Bellows. 1995. Body composition and metabolic profiles associated with puberty in beef heifers. J. Anim. Sci. 73:3409–3420.

Hammond, A. C., W. E. Kunkle, D. B. Bates, and L. E. Sollenberger. 1993. Use of blood urea nitrogen concentration to predict response to protein or energy supplementation in grazing cattle. In: Proc. XVII Int. Grassl. Congr. p 1989. New Zealand Grassland Association, Palmerson North.

Hammond, A. C., and T. A. Olson. 1994. Rectal temperature and grazing time in selected beef cattle breeds under tropical summer conditions in subtropical Florida. Trop. Agric. 71:128–134.

Hammond, A. C., T. A. Olson, C. C. Chase, Jr., E. J. Bowers, R. D. Randel, C. N. Murphy, D. W. Vogt, and A. Tewolde. 1996. Heat tolerance in two tropically adapted *Bos taurus* breeds, Senepol and Romosinuano, compared with Brahman, Angus, and Hereford cattle in Florida. J. Anim. Sci. 74:295–303.

Hammond, A. C., L. J. Padgett, and M. J. Williams. 1992. Relative feeding value of rhizoma perennial peanut hay as a supplement to bahiagrass hay for wintering cows and heifers. Prof. Anim. Sci. 8:48–54.

Hammond, A. C., T. S. Rumsey, and G. L. Haaland. 1984. Estimation of empty body water in steers by urea dilution. Growth 48: 29–34.

Hammond, A. C., T. S. Rumsey, and G. L. Haaland. 1988. Prediction of empty body components in steers by urea dilution. J. Anim. Sci. 66:354–360.

Hopper, H. W., S. E. Williams, D. J. Byerley, M. M. Rollosson, P. O. Ahmed, and T. E. Kiser. 1993. Effect of prepubertal body weight gain and breed on carcass composition at puberty in beef heifers. J. Anim. Sci. 71:1104–1111.

Hupp, H. D. 1981. History and Development of Senepol Cattle. College of the Virgin Islands Agric. Exp. Sta. Rep. 11.

Jones, E. J., J. D. Armstrong, and R. W. Harvey. 1991. Changes in metabolites, metabolic hormones, and luteinizing hormone before puberty in Angus, Braford, Charolais, and Simmental heifers. J. Anim. Sci. 69:1607–1615.

Laster, D. B., H. A. Glimp, and K. E. Gregory. 1972. Age and weight at puberty and conception in different breeds and breed-crosses of beef heifers. J. Anim. Sci. 34:1031–1036.

Marsh, W. H., B. Fingerhut, and H. Miller. 1965. Automated and manual direct methods for determination of blood urea. J. Clin. Chem. 11:624–627.

McCaughey, W. P., L. M. Rutter, and J. G. Manns. 1985. Effect of glucose infusion (INF) on metabolic and reproductive function in the postpartum (PP) beef cow. J. Anim. Sci. 61(Suppl. 1): 186 (Abstr.).

McShane, T. M., K. K. Schillo, J. A. Boling, N. W. Bradley, and J. B. Hall. 1989. Effects of recombinant DNA-derived somatotropin and dietary energy intake on development of beef heifers: I. Growth and puberty. J. Anim. Sci. 67:2230–2236.

Meinert, R. A., C.-M. J. Yang, A. J. Heinrichs, and G. A. Varga. 1992. Effect of monensin on growth, reproductive performance, and estimated body composition in Holstein heifers. J. Dairy Sci. 75:257–261.

Rutter, L. M., and J. G. Manns. 1986. Changes in metabolic and reproductive characteristics associated with lactation and glucose infusion in the postpartum ewe. J. Anim. Sci. 63:538–545.

Rutter, L. M., and J. G. Manns. 1987. Hypoglycemia alters pulsatile luteinizing hormone secretion in the postpartum beef cow. J. Anim. Sci. 64:479–488.

Rutter, L. M., and J. G. Manns. 1988. Follicular phase gonadotropin secretion in cyclic postpartum beef cows with phlorizin-induced hypoglycemia. J. Anim. Sci. 66:1194–1200.

SAS. 1985. SAS/STAT® Guide for Personal Computers (6th Ed.). SAS Inst. Inc., Cary, NC.

Simpson, R. B., J. D. Armstrong, R. W. Harvey, D. C. Miller, E. P. Heimer, and R. M. Campbell. 1991. Effect of active immunization against growth hormone-releasing factor on growth and onset of puberty in beef heifers. J. Anim. Sci. 69:4914–4924.

Williams, M. J., and A. C. Hammond. 1996. Continuous intensive grazing management of bahiagrass pastures for cows and calves. In: M. J. Williams (Ed.) Proc. Am. Forage Grassl. Council 5:76. AFGC, Georgetown, TX.

Williams, M. J., A. C. Hammond, W. E. Kunkle, and T. H. Spreen. 1991. Stocker performance on continuously grazed mixed grass-rhizoma peanut and bahiagrass pastures. J. Prod. Agric. 4: 19–24.

Wiltbank, J. N., K. E. Gregory, L. A. Swiger, J. E. Ingalls, J. A. Rothlisberger, and R. M. Koch. 1966. Effects of heterosis on age and weight at puberty in beef heifers. J. Anim. Sci. 25:744–751.

Wiltbank, J. N., C. W. Kasson, and J. E. Ingalls. 1969. Puberty in crossbred and straightbred beef heifers on two levels of feed. J. Anim. Sci. 29:602–605.

Yelich, J. V., R. P. Wettemann, H. G. Dolezal, K. S. Lusby, D. K. Bishop, and L. J. Spicer. 1995. Effects of growth rate on carcass composition and lipid partitioning at puberty and growth hormone, insulin-like growth factor I, insulin, and metabolites before puberty in beef heifers. J. Anim. Sci. 73:2390–2405.

Citations

This article has been cited by 1 HighWire-hosted articles:
http://jas.fass.org#otherarticles